# Criticality Assessment of Phosphorus regarding Specificity and Functionality

Materials Resource Management

| Study | Definition of criticality | Goal of the study | Number of considered materials | Used criteria | Remark | Use of criteria | Criteria | Mining | Processing | Use | Re-Phase | Macro level / Micro level (Sensitivity Analyses) | Materials Criticality/ Functional Criticality | Practical relevance | Materials definition (Compounds) | Phosphorus considered |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| European Commission 2010 + 2014 | Raw material is labelled critical when the risks of supply shortage and their impacts on the economy are higher compared with most of the other raw materials. | Identification of critical raw materials for the EU | 41 (2010) / 54 (2014) | Economic Importance for the EU | Mega sectors | | | - | ✓ | ✓ | - | The study analyses criticality on a macro level. Sensitivity analyses are not yet considered. | The study addresses the materials criticality. Functional criticality is not yet considered. | Based on the practical relevance it is challenging to make practical recommendations. | There is no raw material definition used. | 2010 No / 2014 Yes |
| | | | | Stability and Level of Country Concentration | Supply Risk Part 1 (WGI-World Governance Indicators and Country Concentration of Producing Countries) | | | ✓ | - | - | - | | | | | |
| | | | | Substitutability | Supply Risk Part 2 | | | | ✓ | ✓ | | | | | | |
| | | | | Recycling | Supply Risk Part 3 | | | | - | - | ✓ | | | | | |
| | | | | Environmental Country Risk | (EPI-Environmental Performance Index and Country Concentration of Producing Countries) | | | ✓ | - | - | - | | | | | |

| Colour code | Quantitative | Qualitative | Considered | Not Considered | Not Applicable |
|---|---|---|---|---|---|
| | | | ✓ | - | |

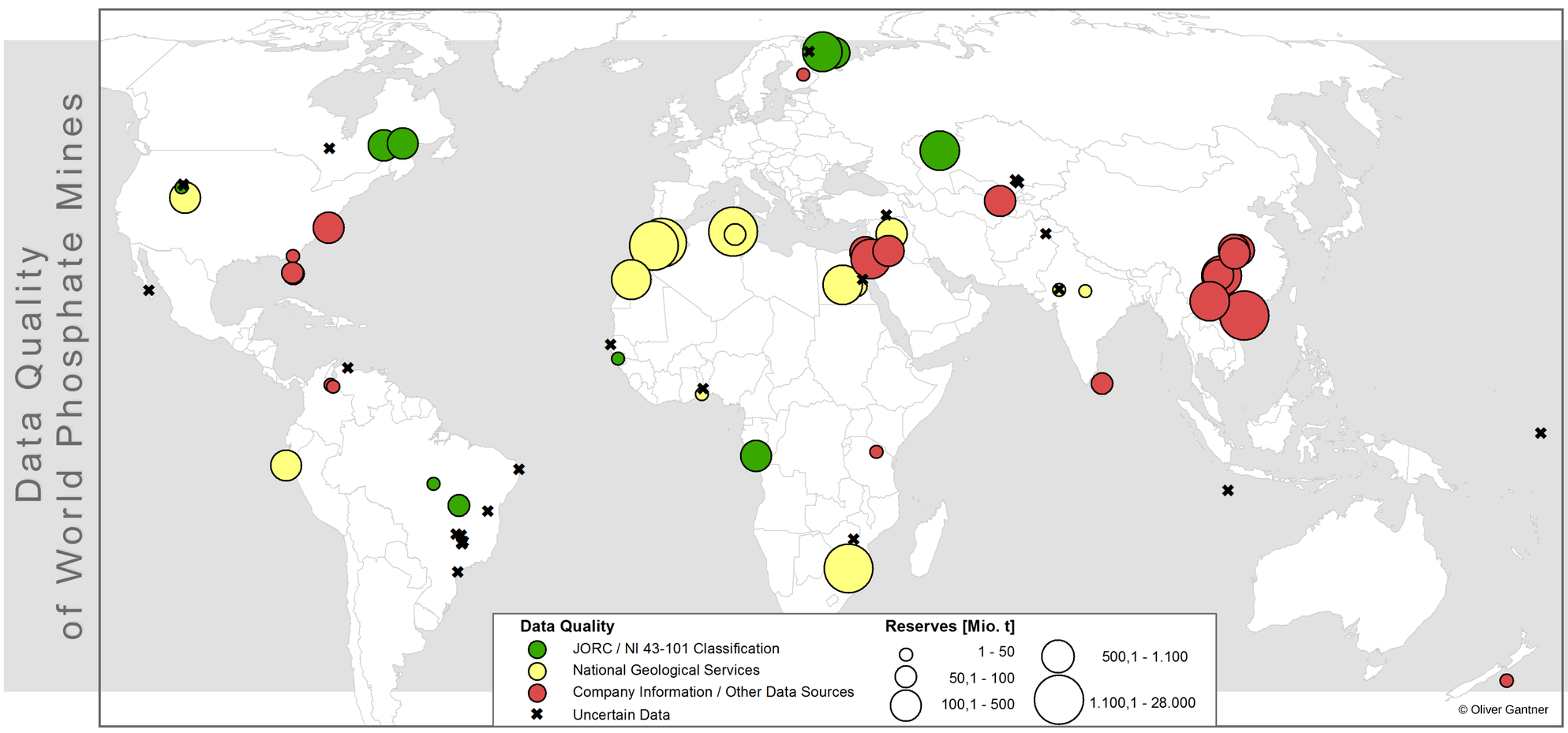
## Status quo

The assessment of raw material criticality is a relatively new field of research that created several studies with more or less the same results in the past eight years. Although addressing different system boundaries and target groups, the use of almost the same quantitative indicators led to similar results. In consequence no methodological development has taken place which becomes evident in the recent EU study “critical raw materials for the EU” [1-3]. Even though phosphorus or phosphate rock is yet underrepresented in this kind of studies, it exemplifies in particular the inherent methodical challenges. In conclusion the aggregation of the information puts the validity and relevance into question. However an assessment on an overall or macro-level is necessary, but has to be additionally complemented by contextualized research using specific and functional criteria. For instance using mine specific information beyond USGS Information.

The value und production chain of industrial phosphate applications is different to those of fertilizers e.g. further purification is needed; the production plants are different ones, the subsequent manufacturers are different ones [4].

## Specificity

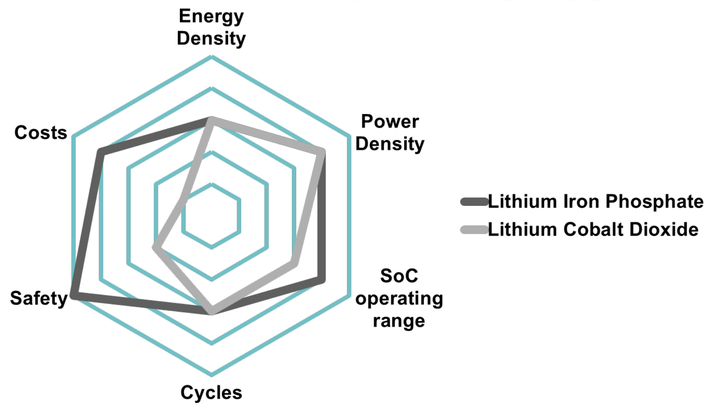
For the emerging lithium ion battery technology multiple electrode materials can be applied, in particular lithium cobalt dioxide ($LiCoO_2$), lithium iron phosphate ($LiFePO_4$) or lithium hexafluorophosphate ($LiPF_6$) [5]. While $LiPF_6$ can only be gainded by the $P_4$-production route, $LiFePO_4$ can also be produced through PPA. The high country concentration of $P_4$-production in Asian countries is facing different issues than fertilizer supply. In addition this context view balances between the loss of phosphates in battery technology at EoL and the use of cobalt as critical metal. This approach requires an in-depth analysis of the value and supply chain of the respective specific function and can be seen as a sensitivity analysis of criticality. Following industrial phosphorus and phosphate applications are used to demonstrate the necessity for this differentiated view depending on the specific P-function.




| Selected examples for specific and functional criteria | $LiFePO_4$ | $LiPF_6$ | $LiCoO_2$ |
|---|---|---|---|
| Phosphorus production route | P4 / PPA | P4 | - |
| Potential constraints in Processing | Capacity<br>Market Concentration | Capacity<br>Market Concentration | RoHS<br>Capacity<br>Market Concentration |
| Potential constraints in Use | - | - | Conflict Mineral |
| Potential constraints in Re-Phase | Recycling | Recycling | Recycling |

## Functionality

Strengths and weaknesses in current cathode materials for electro mobility according to [5]




## References


[1] Achzet, B.; Helbig, C. (2013): How to evaluate raw material supply risks—an overview. Resource Policy. DOI: 10.1016/j.resourpol.2013.06.003. http://www.sciencedirect.com/science/article/pii/S0301420713000445
[2] Glöser, S.; Faulstich, M. (2014): Analyse kritischer Rohstoffe durch Methoden der Multivariaten Statistik. 3. Symposium Rohstoffeffizienz und Rohstoffinnovationen; Nürnberg. http://www.r-cubed-research.eu/page_support/Analyse_kritischer_Rohstoffe_durch_Methoden_Gloeser.pdf
[3] European Commission (2014): Report on critical raw materials for the EU. Report of the Ad-hoc Working Group on defining critical raw materials. http://ec.europa.eu/enterprise/policies/raw-materials/files
[4] Gantner, O.; Schipper, W.; Weigand, J.J. (2014): Technological Use of Phosphorus: The Non-fertilizer, Non-feed and Non-detergent Domain. In. Sustainable Phosphorus Management: A Global Transdisciplinary Roadmap. Scholz, R.W.; Roy, A.H.; Brand, F.S., Hellums, D.T.; Ulrich, A.U.; Springer, Heidelberg; 299 Seiten. http://www.springer.com/environment/sustainable+development/book/978-94-007-7249-6
[5] Korthauer, R. (2013): Handbuch Lithium-Ionen-Batterien. Springer, Berlin Heidelberg. 436 Seiten. DOI 10.1007/978-3-642-30653-2 http://www.springer.com/springer+vieweg/energie+%26+umwelt/energiequellen,+energiewirtschaft/book/978-3-642-30652-5



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